CLAIMS

1. A method for measuring the point defect distribution of a silicon single crystal ingot, comprising

(a1) a step of preparing a sample for measurement including regions [V], [Pv], [Pi] and [I] by cutting to an axial direction a silicon single crystal ingot which is pulled up by changing a pulling-up speed from silicon melt so as to include the central axis of the single crystal ingot,

(b1) a step of preparing a first sample and a second sample by dividing the sample for measurement into two so as to be symmetrical against the central axis of the ingot,

(c1) a step of coating a first transition metal solution dissolving a first transition metal at a concentration of 1 to 1000 ppm on the surface of the first sample to stain the sample with the metal,

(d1) a step of coating a second transition metal solution dissolving a second transition metal different from the first transition metal at a concentration of 1 to 1000 ppm on the surface of the second sample to stain the sample with the metal,

(e1) a diffusion thermal treatment step of thermally treating the first and second samples stained with the metals at 600°C to 1150°C for 0.5 hour to 30 hours under argon, nitrogen, oxygen, hydrogen or mixed gas atmosphere thereof and diffusing the first and second transition metals which are respectively coated on the surface of the

first and second samples into the inside of the samples,

(f1) a step of respectively measuring recombination lifetimes in the whole of the first and second samples which are thermally treated,

(g1) a step of overlapping the vertical measurement of the first sample of the step (f1) on the vertical measurement of the second sample, and

(h1) a step of respectively specifying the boundary between the regions [Pi] and [I] and the boundary between the regions [V] and [Pv] from the measurement result of the step (g1).

Provided that the region [V] is a region having defects where the vacancy type point defect is dominant and excessive vacancies are agglomerated, the region [Pv] is a region having defects where the vacancy type point defect is dominant and vacancies are not agglomerated, the region [Pi] is a region having defects where the interstitial silicon type point defect is dominant and interstitial silicons are not agglomerated, and the region [I] is a region having defects where the interstitial silicon type point defect is dominant and interstitial silicons are agglomerated.

2. A method for measuring the point defect distribution of a silicon single crystal ingot, comprising

(a2) a step of preparing a sample for measurement including regions [V], [Pv], [Pi] and [I] by cutting to an axial direction a silicon single crystal ingot which is

pulled up by changing a pulling-up speed from silicon melt so as to include the central axis of the single crystal ingot,

(b2) a step of preparing a first sample and a second sample by dividing the sample for measurement into two so as to be symmetrical against the central axis of the ingot,

(c2) a step of coating a first transition metal solution dissolving a first transition metal at a concentration of 1 to 1000 ppm on the surface of the first sample to stain the sample with the metal,

(d2) a step of coating a second transition metal solution dissolving a second transition metal different from the first transition metal at a concentration of 1 to 1000 ppm on the surface of the second sample to stain the sample with the metal,

(e2) a diffusion thermal treatment step of thermally treating the first and second samples stained with the metals at 600°C to 1150°C for 0.5 hour to 30 hours under argon, nitrogen, oxygen, hydrogen or mixed gas atmosphere thereof and diffusing the first and second transition metals which are respectively coated on the surface of the first and second samples into the inside of the samples,

(f2) a step of respectively measuring recombination lifetimes in the whole of the first and second samples which are thermally treated,

(g2) a step of overlapping the vertical measurement of the first sample of the step (f2) on the vertical

measurement of the second sample,

(i2) a step of determining the vertical concentration of the first transition metal by the TID method with respect to the first sample which is thermally treated,

(j2) a step of determining the vertical concentration of the second transition metal by the DLTS method with respect to the second sample which is thermally treated,

(k2) a step of preparing a correlation straight line between the concentration of the first transition metal and the recombination lifetime from the vertical measurement result in the first sample of the step (f2) and the measurement result of the step (i2),

(l2) a step of preparing a correlation straight line between the concentration of the second transition metal and the recombination lifetime from the vertical measurement result in the second sample of the step (f2) and the measurement result of the step (j2), and

(m2) a step of respectively specifying the boundary between the regions [V] and [Pv] and the boundary between the regions [Pi] and [I] from the measurement result of the step (g2), the correlation straight line of the step (k2) and the correlation straight line of the step (l2).

Provided that the regions [V], [Pv], [Pi] and [I] have the same meaning as those respectively described in Claim 1, the TID method is a method of quantifying the concentration of Cu dissolved in a silicon single crystal from the analysis of transient capacitance property of a

metal semiconductor junction diode, and the DLTS method is a method of applying pulse voltage to a positive direction in a condition in which electric field to a reverse direction against the junction (or interface) and capturing a carrier with a level in a depletion layer.

3. The measurement method according to Claim 1, wherein the first transition metal is Cu or Fe and the second transition metal is Ni or Co.

4. The measurement method according to Claim 2, wherein the first transition metal is Cu and the second transition metal is Fe.

5. The measurement method according to Claim 1 or 2, wherein the diffusion thermal treatment step of the first and second transition metals in the step (e1) or (e2) is a thermal treatment at 600°C to 1150°C for 0.5 hour to 24 hours.

6. The measurement method according to Claim 1 or 2, wherein the measurement of the recombination lifetime in the step (f1) or (f2) is measured using the LM-PCD (laser/microwave photoconductance decay method).

7. The measurement method according to Claim 1 or 3, further comprising a step of selectively etching the surface of the second sample which is thermally treated with the step (e1) when the second transition metal with which the second sample is metal-stained is Ni.

8. A method for measuring the point defect distribution of a silicon single crystal ingot, comprising

(a3) a step of preparing a sample for measurement including regions [V], [Pv], [Pi] and [I] by cutting to an axial direction a p-type silicon single crystal ingot which is pulled up by changing a pulling-up speed from silicon melt doped with boron,

(b3) a step of coating a transition metal solution dissolving a transition metal M at a concentration of 1 to 1000 ppm on the surface of the sample to stain the sample with the metal,

(c3) a diffusion thermal treatment step of rapidly charging the sample stained with the metal into a thermally treating furnace which is retained at a first temperature of 600°C to 900°C, under argon, nitrogen, oxygen, hydrogen or mixed gas atmosphere thereof, thereby rapidly heating the sample at a temperature raising speed of 3.3°C/min. or more to thermally treat the sample for 0.5 hour to 4 hours, rapidly cooling the sample at a temperature cooling speed of 3.3°C/min. or more by rapidly taking out the sample from the thermally treating furnace and diffusing the transition metal M which is coated on the surface of the sample into the inside of the sample,

(d3) a silicide forming thermal treatment step of rapidly charging the sample into a thermally treating furnace which is retained at a second temperature of 450°C to 550°C lower than the first temperature by 150°C to 450°C, under argon, nitrogen, oxygen, hydrogen or mixed gas atmosphere thereof, thereby rapidly heating the sample at a

temperature raising speed of 3.3°C/min. or more to thermally treat the sample for 0.5 hour to 4 hours, rapidly cooling the sample at a temperature cooling speed of 3.3°C/min. or more by rapidly taking out the sample from the thermally treating furnace and forming metal silicide from the transition metal M which is diffused into the inside of the sample,

(e3) a dissolution thermal treatment step of rapidly charging the sample into a thermally treating furnace which is retained at a third temperature of 900°C to 1100°C higher than the second temperature by 450°C to 550°C, under argon, nitrogen, oxygen, hydrogen or mixed gas atmosphere thereof, thereby rapidly heating the sample at a temperature raising speed of 3.3°C/min. or more to thermally treat the sample for 0.5 hour to 4 hours, rapidly cooling the sample at a temperature cooling speed of 3.3°C/min. or more by rapidly taking out the sample from the thermally treating furnace and dissolving the metal silicide which is formed in the inside of the sample,

(f3) a step of measuring the concentration of the recombination center which the transition metal M forms in the whole sample which undergoes the dissolution thermal treatment and determining a correlation function from the measurement result,

(g3) a step of measuring the diffusion length of minor carrier in the whole sample which undergoes the dissolution thermal treatment,

(h3) a step of injecting heat or optical energy in the sample,

(i3) a step of measuring the diffusion length of minor carrier in the whole sample in which the heat or optical energy is injected,

(j3) a step of determining the difference of the diffusion lengths of minor carrier from the measurement result of the step (g3) and the measurement result of the step (i3), and

(k3) a step of specifying the regions [Pv] and [Pi] in the sample and boundary thereof from the correlation function obtained in the step (f3) and the difference of the diffusion lengths of minor carrier obtained from the step (j3).

Provided that the region [V] is a region having defects where the vacancy type point defect is dominant and excessively saturated vacancies are agglomerated, the region [Pv] is a region having defects where the vacancy type point defect is dominant and vacancies are not agglomerated, the region [Pi] is a region having defects where the interstitial silicon type point defect is dominant and interstitial silicons are not agglomerated, and the region [I] is a region having defects where the interstitial silicon type point defect is dominant and interstitial silicons are agglomerated.

9. The measurement method according to Claim 8, wherein the transition metal M is Fe.

10. The measurement method according to Claim 8, wherein the minor carrier diffusion lengths in the steps (g3) and (i3) are measured using the SPV (surface photovoltage method).

11. The measurement method according to Claim 8, wherein the concentration of recombination center of the transition metal M in the step (f3) is measured using the DLTS (deep level transient spectroscopy).